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**ORIGINAL RESEARCH ARTICLE**

# Comparative performance of the traditional and improved methods of menthol mint sucker production on farmer's field in Barabanki district of Uttar Pradesh- A case study

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## ABSTRACT

*Menthol mint (Mentha arvensis) is a globally recognized commercial crop with a substantial share in the international trade because of its utility in the food, cosmetics, aroma, and pharmaceutical industries. The natural production of menthol still contributes about 70% of the total global supply of menthol, out of which mint grown by Indian farmers has a significant share. The quality of seeds/planting material is a critical factor in the economical production of every crop, and suckers are the planting material in case of menthol mint. Considering the impact of the planting method on the quantity and quality of sucker production, this study was aimed at evaluating the comparative performance of two methods of planting, i.e., newly developed ridge-bed planting and traditional flat-bed planting, on two popular varieties, Kosi and CIM-Kranti, at farmer's fields in the Barabanki district of Uttar Pradesh. The data was collected through direct interaction with farmers involved in the cultivation of this crop. According to data collected from the Block Masauli, Tehsil Fatehpur, and Jaitpur regions of district Barabanki, Uttar Pradesh, India, the ridge-bed plantation method is more productive in terms of sucker yield (37.7%), herb yield (19.3%), and essential oil yield (46.1%) than the flat-bed plantation method, resulting in a higher net return (40.3%) for farmers. The data collected and analyzed during this study concludes that the improved plantation method has played a vital role in the time-bound production of quality planting material (suckers) and thus assisted the farmers in better farming of menthol mint to achieve higher economic gains.*



## INTRODUCTION

*Mentha arvensis* L. (Menthol mint) is an important member of the *Lamiaceae* family. It is commonly known as corn mint. India is the leading producer, accounting for 80–85% of total production and a significant supplier to the flavor, pharmaceutical, and food industries (Shrivastava, 2009; Villanti *et al.*, 2021). The essential oil also possesses anti-microbial properties (Chagas *et al.*, 2020; Patel *et al.*, 2021). Western Central Asia is where the plant originated and is also widely distributed in the Eastern Himalayas, North

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America, and Siberia. Time of sucker plantation (January to March), transplantation (March to April), and plantation of stored suckers (March to April) all affect essential oil yield in different mentha varieties (Bahl *et al.*, 2000; Soltanbeigi *et al.*, 2021). Menthol mint is a thriving commercial crop cultivated in the Indo-Gangetic regions of northern India. The recent surge in the total cultivation area is due to high menthol-containing varieties such as Kosi, CIM-Kranti, and CIM-Unnati developed by CSIR-CIMAP, Lucknow. It is a summer season crop mainly cultivated in the plains of northern India as a commercial crop. In India, 2.5-3.0 lac hectares of land are utilized to cultivate menthol mint, contributing to around 25,000-30,000 metric tons of essential oil production.

The underground parts of menthol mint, also known as suckers, serve as the primary planting material for mint cultivation since this crop


**Figure 1:** Map of the Barabanki district in Uttar Pradesh. The three sites of data collection are highlighted in a circle.

reproduces through vegetative propagation. Suckers or rhizomes grow multi-directionally up to a depth of 15 cm in soil (Chand *et al.*, 2004). In India, an extensive land area requires planting material (suckers or rhizome), and there is a gap between the demand and supply of suckers to Farmers. This problem needs to be addressed by increasing the sucker production to assist the farmers in easy and time-bound procurement of planting material. The traditional methods for producing quality suckers of menthol mint, which are labor- and time-intensive processes, require more investment of land and other farming resources, resulting in a longer duration of time in sucker production for the next crop (Nilofer *et al.*, 2015). The efficiency and agricultural output of ridge-bed planting have been validated by several other studies conducted in the past, including Singh *et al.* (2003), Tian *et al.* (2003), and Zhou *et al.* (2009). The time-bound availability of adequate planting material plays a vital role in the high fructification of menthol mint. This study compares performance data on sucker production, essential oil yield, morphological, and agronomic parameters for two popular mint varieties cultivated using different planting methods. This study was carried out in the fields/sites of menthol mint growers (farmers) in selected rural areas (i.e., Block Masauli, Tehsil Fatehpur, and Jaitpur region) of Uttar Pradesh, India, to compare the outcomes and benefits of the different planting methods and create awareness amongst the farmers of recent agro-technological advancements for menthol mint sucker production.

## MATERIALS AND METHODS

The performance of the newly developed ridge-bed method and the standard flat-bed sucker production techniques was evaluated in menthol mint at different locations in district Barabanki, Uttar Pradesh. The sample data were collected directly from the farmers, fields. The comparative performance of two verities, Kosi and CIM-Kranti, were also evaluated. Study parameters were selected based on their impact on the commercial success of the crop as compared to the conventional plantation techniques. The most impactful parameters were prioritized during the analysis of data collected.

### Data collection sites

**District Barabanki:** Situated in the territory of Uttar Pradesh state, Barabanki is one of the five districts of the Ayodhya division, which is known as the heart of the Awadh region (Fig. 1). Barabanki is surrounded by several districts, such as Lucknow in the West, Sitapur in the North West, Raebareli in the South, Ayodhya in the East, Amethi in the South East, Gonda and Bahraich in the North East. The entire district can be divided into three major regions, (i) Tarai region, which is distributed in the North East of the district facing river Ghaghra, (ii) the Gomti Par region, situated in South West to South East, and (iii) Har region which is distributed at a similar height to the Gomti Par region. The district receives most of its rain between June to September and sometimes in November to January.

**(a)** ***Tehsil Fatehpur*:** Fatehpur Tehsil is a town in the district of Barabanki, which consists of 86 villages. The majority of its population are farmers involved in the active and large-scale cultivation of menthol mint as a commercial crop. The sucker production and crop cultivation data were collected through field visits in the villages of Fatehpur Tehsil.

**(b)** ***Jaitpur region*:** Jaitpur is a village located in Ramnagar Tehsil of the district of Barabanki. Population-wise, it is a medium-sized village where most of the population is involved in agriculture. The farmers of these villages grow menthol mint as a commercial crop. The inputs of farmers related to mint crop cultivation, planting material production, and harvesting were recorded during this study.

**(c)** ***Block Masauli*:** Masauli is a village and a block located in Tehsil Nawabganj in the district of Barabanki. Population-wise, it is a large village where most families are actively involved in agriculture. Farmers in this area are also active growers of menthol Mint, and a part of the data for this study was collected through interaction with them.

### Data collection method

Before the field visit of different locations in Barabanki, a detailed spreadsheet with a relevant questionnaire was prepared in the local language

(Hindi). The required information was recorded during the interaction with farmers on their field site. The morphological parameters were observed in field-grown plants, and the data were recorded accordingly. The input of farmers is the benefits of advanced cultivation methods over conventional ones were recorded. The commercial success of new varieties with the implementation of new planting methods was also assessed through interaction with farmers, and agronomical data were collected. The problems related to sucker production in terms of quality and quantity were identified through the detailed interaction with farmers involved in the large-scale cultivation of this crop. Information on the latest advancements in menthol cultivation and sucker production was delivered to the farmers.

## RESULTS AND DISCUSSION

During this study, multiple observations were taken in to account to compare two varieties (Kosi and CIM-Kranti) that were cultivated using both of the planting methods of sucker production, i.e., flat-bed planting and ridge-bed planting, in different villages of Fatehpur Tehsil, Masauli block, and the Jaitpur region of district Barabanki (Tables 1-9). From the data collected from Tehsil Fatehpur, multiple observations such as plant height, number of branches, number of leaves, leaf stem ratio, sucker yield, herb yield, essential oil percentage, essential oil yield, cost of cultivation, gross return, the net return, and B: C (Benefit: Cost) ratio were recorded and analyzed in the factorial RBD design of field experimentation. The Kosi variety of menthol mint was found to be more productive for all the mentioned parameters, irrespective of planting technique. The ridge-bed plantation method was more productive than the flat-bed plantation as the B: C ratio (Benefit: Cost) was recorded at 4.4 in the case of ridge plantation compared to 2.6 in the case of flat-bed plantation (Table 3). Optimum uptake of water and nutrients and more efficient temperature regulation are factors behind the better productivity of a ridge-bed plantation compared to a flat-bed plantation. A similar trend was observed in the CIM-Kranti variety of menthol mint, where crops cultivated on ridges performed better than flat fields. Plant height, sucker yield, leaf-to-stem ratio, herb yield, essential oil yield, and B: C ratio was better in crops cultivated on ridges (Tables 1, 2). The average sucker yield in flat-bed planting was recorded at 152.11 q $ha^{-1}$, whereas the ridge-bed planting method yielded 244.46 q $ha^{-1}$ (Table 2). The performance of Kosi in terms of sucker yield (225 q $ha^{-1}$) and essential oil yield (55.38 kg $ha^{-1}$) was better than that of CIM-Kranti, where sucker yield (140 q $ha^{-1}$) and essential oil yield (45.60 kg $ha^{-1}$) were recorded as low. The performance of the ridge-bed planting method was better in all parameters

**Table 1:** Effect of planting method on the growth parameters of menthol mint grown in Fatehpur Tehsil of the district Barabanki.

| Observation / Planting method | Plant height (cm) | No. of branches$^{-1}$ plant | No. of leaves$^{-1}$ plant | L:S ratio |
|---|---|---|---|---|
| Cultivars | | | | |
| Kosi | 52 | 19 | 385 | 1.24 |
| CIM-Kranti | 56 | 24 | 418 | 1.27 |
| SEm± | 1.15 | 0.40 | 5.11 | 0.04 |
| CD at 5% | 3.44 | 1.54 | 21.01 | 0.12 |
| Planting methods | | | | |
| Flat-bed planting | 48 | 18 | 358 | 1.15 |
| Ridge bed planting | 52 | 22 | 388 | 1.18 |
| SEm± | 1.22 | 0.44 | 6.88 | 0.03 |
| CD at 5% | 3.55 | 1.65 | 25.22 | 0.10 |
| Variety (V) | 2.21 | 1.55 | 18.44 | 0.14 |
| Planting method (M) | 1.58 | 1.22 | 12.22 | 0.11 |
| V×M | NS | NS | 9.65 | NS |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

**Table 2:** Effect of planting method on the yield attributes of menthol mint grown in Fatehpur Tehsil of the district Barabanki.

| Observation / Planting method | Sucker yield (kg $m^{-2}$) | Sucker yield (q $ha^{-1}$) | Herb yield (q $ha^{-1}$) | Essential oil percentage (%) | Essential oil yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| Cultivars | | | | | |
| Kosi | 2.25 | 225 | 92.30 | 0.60 | 55.38 |
| CIM-Kranti | 1.40 | 140 | 114.0 | 0.40 | 45.60 |
| SEm± | 0.15 | 2.65 | 1.35 | 0.02 | 0.85 |
| CD at 5% | 0.95 | 8.15 | 5.66 | 0.05 | 2.66 |
| Planting methods | | | | | |
| Flat-bed planting | 1.52 | 152.11 | 85.14 | 0.43 | 40.1 |
| Ridge bed planting | 2.44 | 244.46 | 105.52 | 0.65 | 74.3 |
| SEm± | 0.16 | 2.85 | 1.22 | 0.03 | 0.95 |
| CD at 5% | 0.88 | 7.65 | 6.02 | 0.06 | 2.85 |
| Variety (V) | 0.77 | 7.22 | 5.95 | 0.06 | 2.45 |
| Planting method (M) | 0.91 | 6.11 | 6.55 | NS | 1.85 |
| V×M | NS | 3.25 | 2.15 | NS | 1.65 |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

**Table 3:** Effect of planting method on the economics (Rs $ha^{1}$) of menthol mint grown in Fatehpur Tehsil of district Barabanki

| Observation / Planting method | Cost of cultivation (Rs $ha^{-1}$) | Gross return (Rs $ha^{-1}$) | Net return (Rs $ha^{-1}$) | B: C ratio |
|---|---|---|---|---|
| Cultivars | | | | |
| Kosi | 45800 | 225000 | 179200 | 3.9 |
| CIM-Kranti | 48600 | 160000 | 111400 | 2.3 |
| SEm± | - | 3250 | 2565 | - |
| CD at 5% | - | 10588 | 8865 | - |
| Planting methods | | | | |
| Flat-bed planting | 42200 | 152110 | 109910 | 2.6 |
| Ridge bed planting | 45100 | 244460 | 199360 | 4.4 |
| SEm± | - | 3022 | 2405 | - |
| CD at 5% | - | 9963 | 8791 | - |
| Variety (V) | - | 8305 | 7481 | - |
| Planting method (M) | - | 5745 | 4862 | - |
| V×M | - | 4615 | 4162 | - |

ObservationPlanting method Cost of cultivation (Rs $ha^{-1}$) Gross return (Rs $ha^{-1}$) Net return (Rs $ha^{-1}$) B: C ratio

analyzed during this study. The performance of Menthol mint cultivars planted on ridges was better than cultivars planted on flat-beds, where the net return was recorded at 1,99,360 Rs ha-1 in ridge-bed planting compared to 1,09,910 Rs $ha^{-1}$ in flat-bed planting. Therefore, based on the data collected and analyzed, we can conclude that the ridge-bed plantation method provides a better yield and net return than the flat-bed plantation technique. Moreover, the Kosi variety of menthol mint is more productive and profitable than the CIM-Kranti variety, irrespective of the planting method. The data collected from the Jaitpur region reflects the higher productivity of Kosi than CIM-Kranti (Tables 5, 6) as observed in data obtained from Fatehpur Tehsil areas such as Karondi, Sarsava, Pathakpur, Shevangi, Achaicha, etc. The performance of cultivars in the ridge-bed planting method was better than cultivars planted on flat-beds. In terms of morphological parameters such as plant height, the number of branches, and the number of leaves per plant, CIM-Kranti was better than Kosi (Table 4). The sucker yield in flat-bed planting was recorded at 144.50 q $ha^{-1}$ compared to 232.24 q $ha^{-1}$

**Table 4:** Effect of planting method on the growth parameters of menthol mint grown in Jaitpur region of district Barabanki

| Observation / Planting method | Plant height (cm) | No. of branches/plant | No. of leaves/plant | L:S ratio |
|---|---|---|---|---|
| Cultivars | | | | |
| Kosi | 49 | 18 | 366 | 1.18 |
| CIM-Kranti | 53 | 23 | 397 | 1.21 |
| SEm± | 1.09 | 0.38 | 4.85 | 0.04 |
| CD at 5% | 3.27 | 1.46 | 19.96 | 0.11 |
| Planting methods | | | | |
| Flat-bed planting | 46 | 17 | 340 | 1.09 |
| Ridge bed planting | 49 | 21 | 369 | 1.12 |
| SEm± | 1.16 | 0.42 | 6.54 | 0.03 |
| CD at 5% | 3.37 | 1.57 | 23.96 | 0.10 |
| Variety (V) | 2.10 | 1.47 | 17.52 | 0.13 |
| Planting method (M) | 1.50 | 1.16 | 11.61 | 0.10 |
| V×M | NS | NS | 9.17 | NS |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

**Table 5:** Effect of planting method on the yield attributes of menthol mint grown in Jaitpur region of district Barabanki

| Observation / Planting method | Sucker yield (kg $m^{-2}$) | Sucker yield (q $ha^{-1}$) | Herb yield (q $ha^{-1}$) | Essential oil percentage (%) | Essential oil yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| Cultivars | | | | | |
| Kosi | 2.14 | 213.75 | 87.69 | 0.57 | 52.61 |
| CIM-Kranti | 1.33 | 133.00 | 108.30 | 0.38 | 43.32 |
| SEm± | 0.14 | 2.52 | 1.28 | 0.02 | 0.81 |
| CD at 5% | 0.90 | 7.74 | 5.38 | 0.05 | 2.53 |
| Planting methods | | | | | |
| Flat-bed planting | 1.44 | 144.50 | 80.88 | 0.41 | 38.10 |
| Ridge bed planting | 2.32 | 232.24 | 100.24 | 0.62 | 70.59 |
| SEm± | 0.15 | 2.71 | 1.16 | 0.03 | 0.90 |
| CD at 5% | 0.84 | 7.27 | 5.72 | 0.06 | 2.71 |
| Variety (V) | 0.73 | 6.86 | 5.65 | 0.06 | 2.33 |
| Planting method (M) | 0.86 | 5.80 | 6.22 | NS | 1.76 |
| V×M | NS | 3.09 | 2.04 | NS | 1.57 |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

in the ridge bed planting method (Table 5). The data recorded during the study indicates that the ridge-bed planting method, irrespective of the cultivar, is more productive than the flat-bed plantation method. Similarly, the net return (Rs $ha^{-1}$) in flat-bed plantations was recorded at Rs 95,804.5 $ha^{-1}$ compared to Rs 1,80,737 $ha^{-1}$ in cultivars planted on the ridges (Table 6). The cumulative B: C ratio in flat-bed planted cultivars was recorded at 1.97 compared to 3.51 in the ridge plantation method. Based on the data mentioned in Tables 4, 5, and 6, it can be concluded that the ridge-bed plantation method used for Kosi and CIM-Kranti is more productive than the flat-bed planting method in terms of all the parameters that were studied. The data collected from block Masauli, district Barabanki, were also analyzed. The plantation method and cultivars showed a similar pattern as for the other two tehsils/regions under study. Multiple parameters were considered to study the flat-bed and ridge plantation methods implemented in Kosi and CIM-Kranti cultivation. The trend that we observed in the data obtained from the areas of the Jaitpur region and Fatehpur Tehsil has shown minor deviations. The field performance of CIM-Kranti was better than Kosi in terms of morphological parameters, which were taken into account (Table 7). The total sucker yield ratio

**Table 6:** Effect of planting method on the economics of menthol mint grown in Jaitpur region of district Barabanki

| Observation / Planting method | Cost of cultivation (Rs ha$^{-1}$) | Gross return (Rs ha$^{-1}$) | Net return (Rs ha$^{-1}$) | B: C ratio |
|---|---|---|---|---|
| Cultivars | | | | |
| Kosi | 51000 | 213750 | 162750 | 3.19 |
| CIM-Kranti | 52500 | 133000 | 80500 | 1.53 |
| SEm± | - | 3088 | 2437 | - |
| CD at 5% | - | 10059 | 8422 | - |
| Planting methods | | | | |
| Flat-bed planting | 48700 | 144504.5 | 95804.5 | 1.97 |
| Ridge bed planting | 51500 | 232237 | 180737 | 3.51 |
| SEm± | - | 2871 | 2285 | - |
| CD at 5% | - | 9465 | 8351 | - |
| Variety (V) | - | 7890 | 7107 | - |
| Planting method (M) | - | 5458 | 4619 | - |
| V×M | - | 4384 | 3954 | - |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

**Table 7:** Effect of planting method on the growth parameters of menthol mint grown in Masauli block of the district Barabanki

| Observation / Planting method | Plant height (cm) | No. of branches/plant | No. of leaves/plant | L:S ratio |
|---|---|---|---|---|
| Cultivars | | | | |
| Kosi | 48 | 17 | 373 | 1.20 |
| CIM-Kranti | 50 | 22 | 405 | 1.23 |
| SEm± | 1.05 | 0.39 | 4.96 | 0.04 |
| CD at 5% | 3.10 | 1.49 | 20.38 | 0.12 |
| Planting methods | | | | |
| Flat-bed planting | 45 | 17.46 | 347 | 1.12 |
| Ridge bed planting | 48 | 21.34 | 376 | 1.14 |
| SEm± | 0.43 | 0.03 | 6.67 | 0.43 |
| CD at 5% | 3.22 | 0.10 | 24.46 | 1.60 |
| Variety (V) | 2.07 | 0.14 | 17.89 | 1.50 |
| Planting method (M) | 1.19 | 0.11 | 11.85 | 1.18 |
| V×M | NS | NS | 9.36 | NS |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

(q ha$^{-1}$) in flat-bed planted cultivars was recorded at 147.55 q ha$^{-1}$ as compared to 237.13 q ha$^{-1}$ in cultivars planted on the ridges. Similarly, the comparative production of essential oil was recorded at 38.9 kg ha$^{-1}$ in the flat-bed plantation method as compared to 72.07 kg ha$^{-1}$ in cultivars planted on the ridges (Table 8). In the Masauli areas, the net return was highest in the ridge-based cultivation of mint, where around Rs 1,82,126 ha$^{-1}$ was earned by the farmers. The lowest net return of Rs 94,047 ha$^{-1}$ was earned by farmers who opted for the flat-bed plantation method for both varieties of menthol mint. The morphological parameters, such as plant height, number of branches, and number of leaves that are crucial for total secondary metabolite yield, were observed to be better in the ridge planting method for both the cultivars than the flat-bed plantation methods (Tables 1, 4, 7). This trend was also observed in the data collected from the Fatehpur Tehsil and Jaitpur regions of the district of Barabanki (Table 1-6). The variety (V) and planting method (M) interaction (V×M) was found significant in terms of the number of leaves per plant, sucker yield, herb yield, essential oil yield,

gross return, and net return according to the data collected from all three regions of Barabanki (Tables 1-9). A few key parameters, such as total sucker yield, essential oil yield, cost of menthol cultivation, and the net return obtained from all three different data collection sites, are shown in Fig. 2 and Fig. 3. In terms of suckers and essential oil yield, the ridge-bed plantation performed better than the flat-bed plantation (Fig. 2) at all three data collection sites because this method holds better water and nutrient retention potential of soil, simple weed management, easier irrigation, less water consumption as compared to the conventional method. In addition, better drainage of the soil, and reduced soil compaction, which ultimately lead to better crop productivity in the ridge-bed method. Similarly, in the comparative analysis of the cost of cultivation and net returns in the case of both plantation methods, the ridge-bed technique performed better than the flat-bed method (Fig. 3), possibly due to its multiple field advantages over the conventional method, which makes it a commercially more successful planting technique. The performance of both cultivars was enhanced positively in terms of quality and quantity of desired agronomical characteristics when farmers implemented the ridge-bed plantation method.

**Table 8:** Effect of planting method on the yield attributes of menthol mint grown in Masauli block of the district Barabanki

| Observation / Planting method | Sucker yield (kg $m^{-2}$) | Sucker yield (q $ha^{-1}$) | Herb yield (q $ha^{-1}$) | Essential oil percentage (%) | Essential oil yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| Cultivars | | | | | |
| Kosi | 2.18 | 218.25 | 89.53 | 0.58 | 53.72 |
| CIM-Kranti | 1.36 | 135.80 | 110.58 | 0.39 | 44.23 |
| SEm± | 0.15 | 2.57 | 1.31 | 0.02 | 0.82 |
| CD at 5% | 0.92 | 7.91 | 5.49 | 0.05 | 2.58 |
| Planting methods | | | | | |
| Flat-bed planting | 1.47 | 147.55 | 82.59 | 0.42 | 38.90 |
| Ridge bed planting | 2.37 | 237.13 | 102.35 | 0.63 | 72.07 |
| SEm± | 0.16 | 2.76 | 1.18 | 0.03 | 0.92 |
| CD at 5% | 0.85 | 7.42 | 5.84 | 0.06 | 2.76 |
| Variety (V) | 0.75 | 7.00 | 5.77 | 0.06 | 2.38 |
| Planting method (M) | 0.88 | 5.93 | 6.35 | NS | 1.79 |
| V×M | NS | 3.15 | 2.09 | NS | 1.60 |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

**Table 9:** Effect of planting method on the economics of menthol mint grown in Masauli block of district Barabanki

| Observation / Planting method | Cost of cultivation (Rs $ha^{-1}$) | Gross return (Rs $ha^{-1}$) | Net return (Rs $ha^{-1}$) | B: C ratio |
|---|---|---|---|---|
| Cultivars | | | | |
| Kosi | 53000 | 218250 | 165250 | 3.12 |
| CIM-Kranti | 54500 | 135800 | 81300 | 1.49 |
| SEm± | - | 2995 | 2364 | - |
| CD at 5% | - | 9757 | 8169 | - |
| Planting methods | | | | |
| Flat-bed planting | 53500 | 147547 | 94047 | 1.76 |
| Ridge bed planting | 55000 | 237126 | 182126 | 3.31 |
| SEm± | - | 2785 | 2216 | - |
| CD at 5% | - | 9181 | 8100 | - |
| Variety (V) | - | 7653 | 6894 | - |
| Planting method (M) | - | 5294 | 4480 | - |
| V×M | - | 4252 | 3835 | - |

Letters showing the difference (*$P$> 0.05) = CD at 5%, NS=Non significant, V=Variety, and M=Planting method

## CONCLUSION

In India, farmers cultivate mentha as a commercial crop because it fits well in their cropping system as a summer season crop. The essential oil is the primary commercial use product, which is synthesized in the trichomes present on the plant surface. High air temperature and sunshine during natural cultivation periods favor essential oil synthesis in the plant. It requires an adequate supply of water because of a summer season crop. The share of India in the world market as a menthol producer is accounted for around 80% (30,000 tonnes), in various forms such as menthol crystal, essential oil, and dementholised oil. A total of 3,00,000 hectares of land across the country is under mint cultivation. Menthol mint is a crop of economic importance in India and plays a vital role in uplifting the rural economy and increasing farmers' income, hence improving their economic status. Results of this study indicate that the ridge plantation method implemented in the cultivation of CV Kosi and CIM-Kranti was more productive as compared to the flat-bed plantation method. The crop performance in terms of morphological parameters, yield, and economic value was better in ridge-bed plantation rather than flat-bed plantation method because of multiple favorable factors associated with the ridge-bed plantation technique. The average sucker yield (q $ha^{-1}$) ranged between 140-155 q $ha^{-1}$ in the case of the flat-bed plantation, which was far less as compared to 230-245 q $ha^{-1}$ in the ridge-bed plantation technique in all the three areas of study, *i.e.*, Tehsil Fatehpur, Jaitpur region, and block Masauli of the district Barabanki. Similarly, the net return (Rs $ha^{-1}$) on one crop cycle in case of the flat-bed plantation ranged between Rs 94,000-1,10,000 as compared to Rs 1,80,000- 1,99,500, which was recorded in ridge-bed plantation. Therefore, according to our collected data, the ridge-bed plantation technique was found to be comparatively more profitable. Overall, both plantation methods being implemented in the commercial cultivation of menthol mint are profitable enough for the farmers to cultivate menthol mint as a commercial crop in rural areas. The development of more productive and cost-effective varieties of menthol mint will further promote and expand its large-scale cultivation in rural areas, which will lead to the social and financial improvement of the rural economy and population.

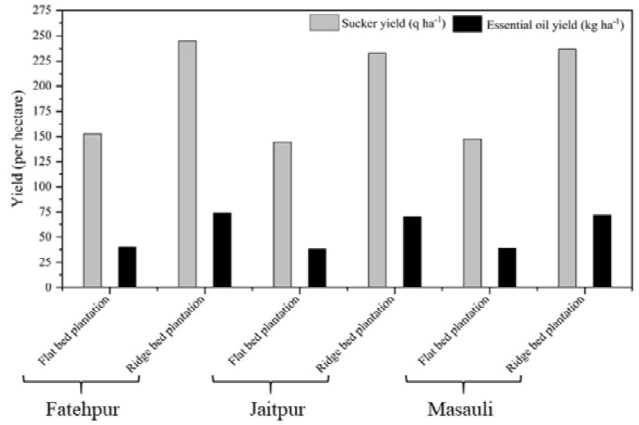


**Figure 2:** Sucker yield (q $ha^{-1}$), and essential oil yield (kg $ha^{-1}$) of mint under two different planting methods at the farmers fields in Fatehpur, Jaitpur, and Masauli region, of Barabanki district.

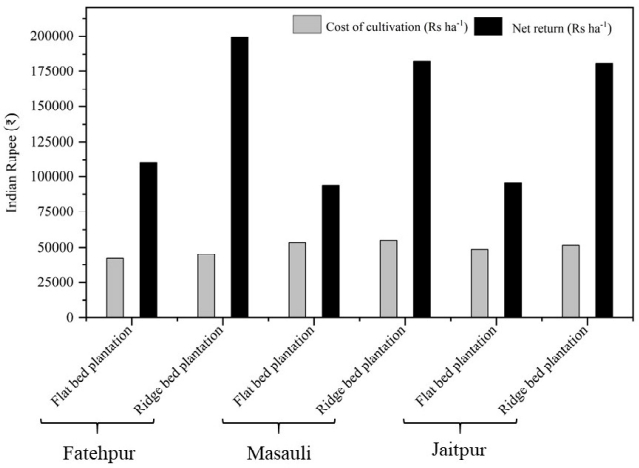


**Figure 3:** Cost of cultivation (Rs $ha^{-1}$) and net return (Rs $ha^{-1}$) obtained from Fatehpur, Jaitpur, and Masauli region of district Barabanki

**Author's contributions:** RS and SS designed the study. RS carried out the field study and collected the data. RS, DK, VG, and SS analyzed the data. DK conducted the statistical analysis. RS wrote the manuscript with input from all authors. SS supervised the field study and findings of this work. VG and SS finalized the manuscript. All the authors have read and agreed to the content of the finalized manuscript.

**Conflicts of interest:** We have no conflicts of interest to disclose.

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**Abbreviations: q ha$^{-1}$** quintal per hectare, **kg ha$^{-1}$** kilogram per hectare, **Rs ha$^{-1}$** rupees per hectare, **cm** centimeter, **SEm** standard error mean

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